Modal Analysis of a Single-layered Gradient Coil Insert for a 4T MRI

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Introduction

The dynamic behavior of a gradient coil insert plays a key role in predicting the acoustic characterization of a MRI scanner [1]. An analytical model of a thin-walled gradient coil prototype was established [2]. This paper investigates the dynamic behavior of a non thin-walled cylinder model due to the fact that most gradient coil inserts belong to the non thin-walled cylinder type. A single-layered gradient coil (X or Y winding only) insert with the geometric ratio of 8.25 has been developed for this purpose. An analytical model of the gradient coil was established. This model is then validated by modal testing and in-situ vibration measurement. Modal shapes of the gradient coil during scanning are revealed for the first time.

Experiments and Results

Parameters of the single-layered gradient coil inset are shown in Table 1. The gradient coil was installed in a 4T MRI scanner using using wooden end plates and 8 screws as shown in Figure 1. An analytical model for the gradient coil insert was built based on modified Love's governing equations [3]. Modal testing of the gradient coil system was performed by using a National Instruments PXI data collector, 3 accelerometers and an impulse hammer. Analytical modes and modal testing results are shown in Figure 2 and Figure 3 respectively. Owing to the gradient coil symmetry in-situ laser vibrometer based vibration measurements for 240 points on the half coil surface were collected and then processed. Experimental mode shapes based on the in-situ measurements are shown in Figure 4.

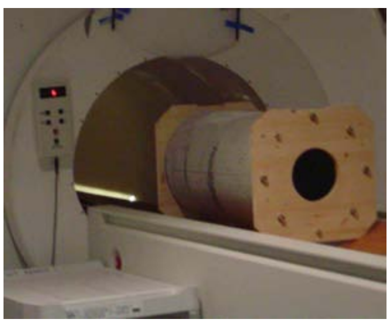

Figure 1. The single-layered gradient coil insert in a 4T MRI

Table 1. Parameters of the gradient coil insert

Length of the gradient coil insert (L)	700 mm
Radius of the coil cylinder (R)	165 mm
Thickness of the coil cylinder (h)	20 mm
Geometric ratio R/h	8.25
Young's modulus (E)	31030×10^{6} Pa
Poisson's ratio	0.32
Mass density	$2241.4\ Kg\ m^{-3}$

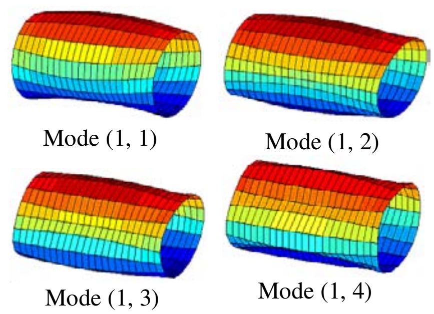

Figure 2. Analytical mode shapes

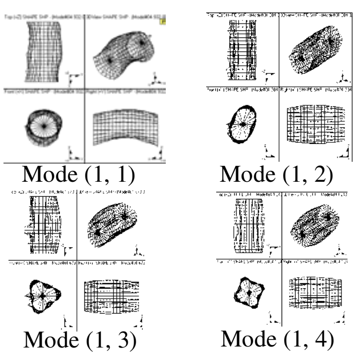

Figure 3. Modal testing results

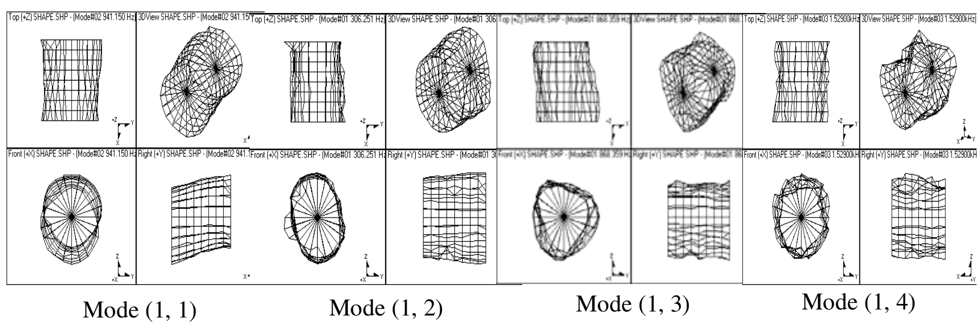

Figure 4. In-situ vibration measurement results

Conclusions

The true mode shapes of a single-layered gradient coil insert excited during scanning in a 4T MRI scanner were measured. An analytical model of the single layered gradient coil was established. The analytical modal results are validated by bench-top modal testing and in-situ laser vibrometer based vibration measurements. The experimental measurements agree very closely with the analytical model predictions. This agreement means that further development of the analytical models could eventually lead to a set of equations that allow gradient designers to optimize the conductor placement in order to satisfy the dynamic response as well as the magnetic response.

References

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